N74-10233

Paper No. 1

SPACE SIMULATION TESTING FOR THE SKYLAB WASTE TANK

C. A. Skinner, R. Gershman, and L. C. Kvinge, *McDonnell Douglas Astronautics Company, Huntington Beach, California*

ABSTRACT

Large scale space simulation testing was accomplished for the Skylab waste tank concept. Investigations included vapor generation rates for liquids dumped into a low pressure tank, sublimation of ice at low pressure, and pressure drop and blockage phenomena for fine mesh filter screens.

The mission of Skylab, America's first space station, will last eight months. Three different three-man crews will inhabit the station: The first crew for one month and the second and third crews for two months each. A wide variety of experiments will be performed including many in the fields of earth resources and astronomy. Because of the need to protect the Skylab external optical environment from contamination which would interfere with these experiments, overboard disposal of waste materials, frequently used in previous missions especially for liquid wastes, had to be avoided. A waste tank concept was established to provide for disposal of all liquid and solid waste material outside of the Skylab habitation area without contaminating the optical environment. This paper describes the waste tank concept with particular emphasis on the small scale and full scale space simulation testing accomplished to develop the hardware necessary to implement the concept.

The structure of the Skylab vehicle is based on the SIVB stage of the Saturn rocket. The crew quarters are built into the 10,000 cubic foot SIVB liquid hydrogen tank and the 2800 cubic foot liquid oxygen tank is used for waste disposal. Solid wastes are transferred from the crew area to the waste tank via a small airlock and liquid wastes are dumped into the waste tank through probes which penetrate the common bulkhead between the two tanks. It was found necessary to vent the waste tank to space since, otherwise, cabin air introduced during trash airlock operations and by leakage would eventually raise the waste tank pressure to a level that would prevent transfer of materials from the crew area. To minimize impact on the Skylab attitude control system, a non-propulsive vent system is used consisting of two short, diametrically opposed ducts located on opposite sides of the vehicle. To avoid venting of liquid, which could contaminate optical surfaces or result in clouds of ice, the vent system is sized to maintain the pressure in the waste tank below the triple point of water. Since practically all liquid wastes consist of water solutions - e.g., wash water, urine - no liquid phase will be present in the waste tank. In order to minimize venting of solids which would interfere with the optical experiments, fine mesh screens are used as filters to trap solid trash and ice formed from flashing of waste liquids in the waste tank. These screens have a nominal filtering capability of two microns. (See sketch in Figure 1.)

The waste tank concept presented a number of unusual thermophysical problems which required vacuum testing, including establishing liquid dump rates and vent system flow rates which would maintain the waste tank pressure below the triple point of water, investigation of fine mesh screen pressure drop and the possibility of screen blockage resulting from freezing of dumped liquids, demonstration of the filtering capability of the screens, and establishing the sublimation rate for frozen liquids trapped within the waste tank.

The test program involved both small scale testing, performed in a bell jar, and full scale testing, performed in the MDAC 39-foot-diameter space chamber. The small scale testing was mainly for the purpose of investigating screen blockage. The test setup provided the capability for dumping water, urine or dust onto small screen samples and for measuring pressure drop across the screen during the dumping and with a known flow rate of nitrogen after each dump. (See Figure 2.)

The full scale test specimen was designed to duplicate actual waste tank volumes, screen areas, and vent size. A production type dump probe was used and was mounted at the actual distance relative to the screen. To assure maximum ice accumulation on the screen, the screen was mounted in a horizontal position with the dump probe above it. Two methods were used to verify that the screen was filtering out all solid materials: The screen was mounted on load cells to measure the ice accumulation and contamination collection plates were installed facing the vent outlets. The load cells also provide data on sublimation rates. Tank pressure and screen pressure drop were measured using MKS Baratron units. (See Figure 3.)

Prediction of waste tank pressure during a dump, which was necessary in order to establish liquid dump rates that would not increase the pressure to the triple point, was first approached in a rather simplified manner. Uniform phase equilibrium was assumed to exist between the ice and the water vapor throughout the tank. The full scale testing showed that this is a reasonable approximation when starting with an empty tank, but the pressure rise rate was found to be smaller and considerably less predictable when significant quantities of ice were accumulated in the tank. (See Figure 4.) The vapor generation rate was apparently reduced by heat transfer between the incoming liquid stream and the cold ice in the tank.

The fine-mesh screens used to prevent venting of solid materials overboard were made of stainless steel wire in a Dutch twill weave. Their two micron filtering capability resulted in an open area of only a few percent which led to concern over pressure drop and potential blockage. While considerable test data were available on screen pressure drop at high flowrates, none were found covering the low Skylab flow range. The small scale testing was accomplished to establish dry pressure drop and blockage characteristics of the screen material and large scale testing was run to determine effects of Skylab geometry on potential blockage.

Results of the dry screen pressure drop tests are shown in Figure 5. These results agree with existing correlations for the higher Reynolds numbers tested, but deviate significantly at very low Reynolds numbers.

When water was dumped on the screen in a vacuum, it was found that a thick layer of porous ice formed which did not significantly increase the pressure drop across the screen. On the other hand, dumping of urine resulted in almost complete blockage of the small scale specimen and very significant blockage in the large scale test. (See Figure 6.) As a result of this testing, it was decided to install a baffle which would prevent impingement of the liquid stream directly on the screen.

Another finding of the urine dump testing was that urine dumped onto residual urine ice, which had an increased concentration of salts due to sublimation, would dissolve the residual salts and depress its vapor pressure to the point where it could freeze only at substantially lower pressures.

In summary, the test program demonstrated that liquid dump rates and vent system flowrates can be predicted accurately enough to provide for maintaining the waste tank pressure below the triple point pressure of water, the range of known pressure drop characteristics for fine mesh screen filters was extended and the effect of contamination on pressure drop was quantitatively assessed, and the effectiveness of the fine mesh screens as filters in a low pressure environment was demonstrated.

References

1. J. C. Armour and J. H. Cannon. Fluid Flow Through Woven Screens. AIChE Journal, Vol 14, No. 3, May 1968.

2. Low Gravity Propellant Control Using Capillary Devices in Larger Scale Cryogenic Vehicles. GDA Report No. GDC-DDB70-009, August 1970.

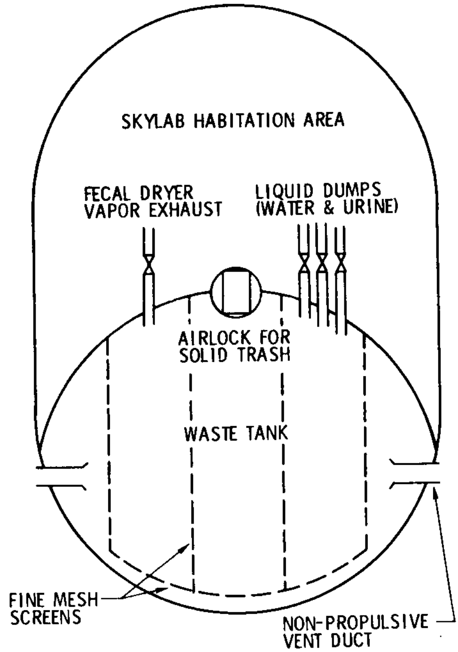

Figure 1. Skylab Overboard Waste Disposal

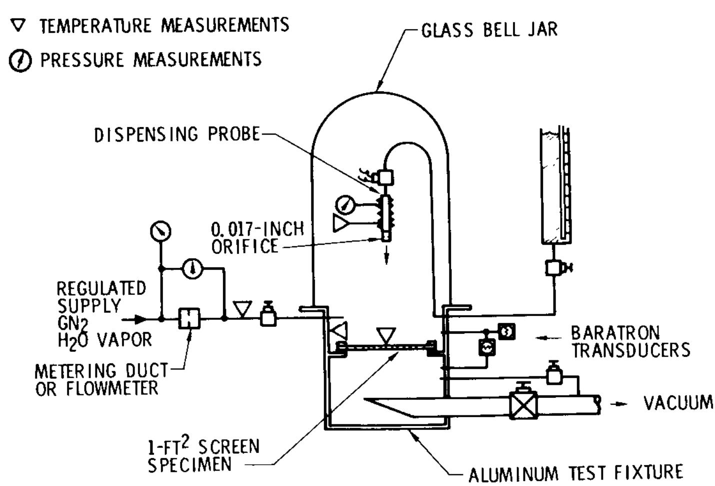

Figure 2. Small Scale Screen Test Setup

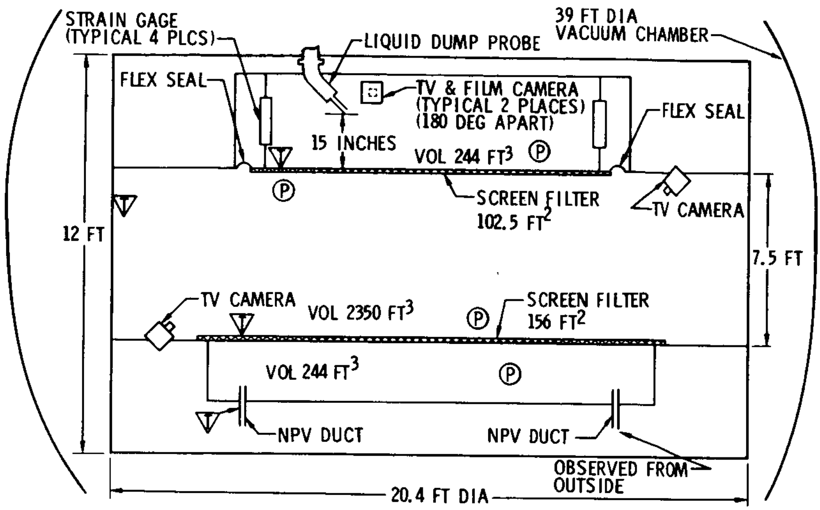

Figure 3. Large Scale Waste Tank Screen Tests

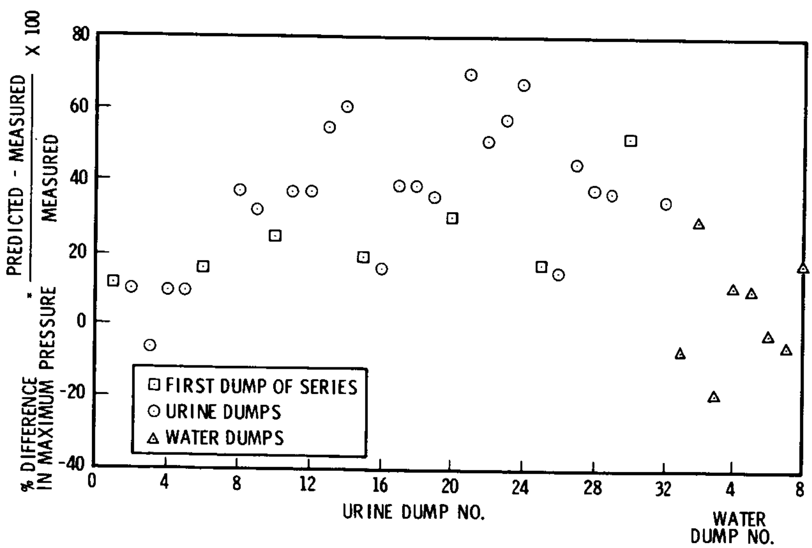

Figure 4. Comparison of Predicted Waste Tank Pressures with Test Results

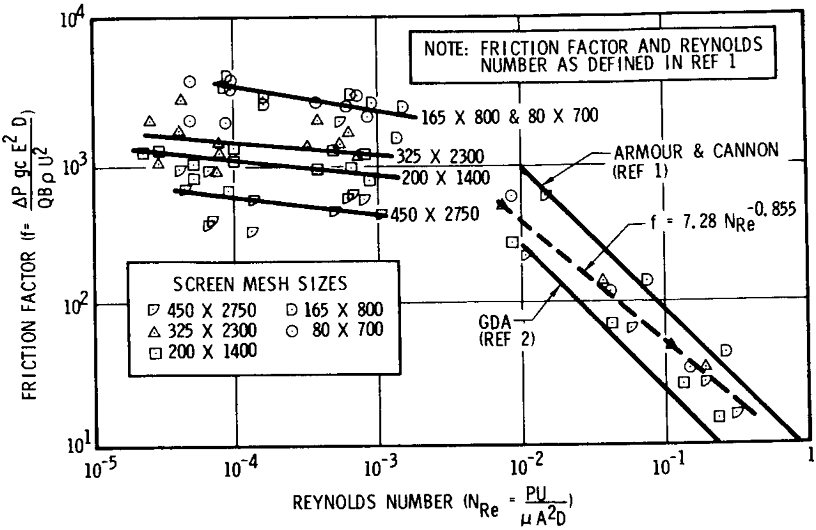

Figure 5. Dutch Twilled Screen ΔP Correlation

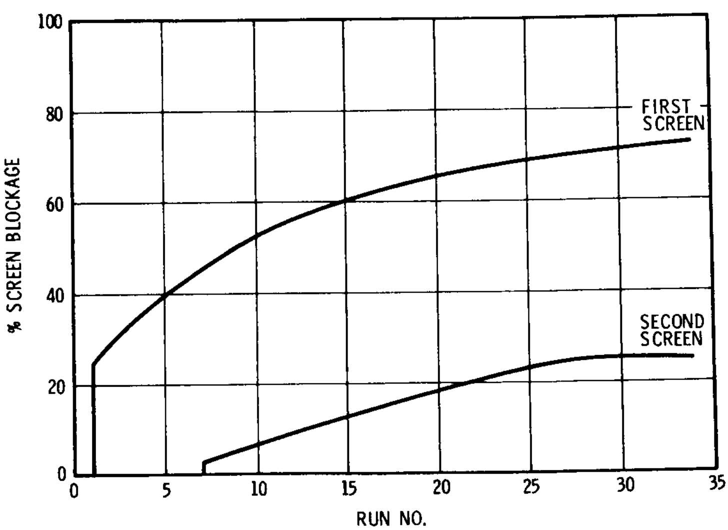

Figure 6. Calculated Screen Blockage